INVESTIGATION OF THE SERVICE RECORD AND EXPLOSION HAZARD OF CHEMICAL FIRE EXTINGUISHERS

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P R E F A C E.

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OBJECT OF THE INVESTIGATION

The object of this investigation was to investigate the service record of chemical fire extinguishers, giving especial attention to the corrosion of these devices; to ascertain which of the protective coatings applied to the extinguisher tanks to prevent corrosion was the most suitable for the purpose; and to determine whether or not extinguishers, having been in service for a number of years and having become more or less corroded, were likely to explode when operated, thereby endangering the life of the operator or persons in the immediate vicinity.

Several explosions of portable chemical extinguishers, in some of which loss of life occurred, have been reported; but inasmuch as only meagre information could be obtained, the reason for the explosion could not be definitely determined. In two cases, if the statements of the party who is nominally the manufacturer of the extinguishers are correct, and these statements were more or less corroborated by the statements of the party who manufactured the tanks for the extinguishers in question, the

trouble was due to faulty design of the joint between the cylinder and the tank bottom, or faulty attachment of the tank bottom to the tank cylinder, or both.

It may be of interest in passing to narrate the incidents in which two 33-gallon portable chemical fire extinguishers exploded.

The following information is quoted verbatim from a report on the explosion of a chemical fire engine.-

> "On the above date an alarm of fire was sounded at 6:45 A. M., the fire being in a negro cabin about 250 yards from the fire station. The __________ Fire Department is a volunteer organization, and the engine in question was made by the __________; it was mounted on two wheels, and the tank had a capacity of 40 gallons, was cylindrical-shaped with round ends, and was equipped with a 'Y' outlet, with a valve at each outlet. One outlet was equipped with a pressure gauge, and the other was threaded for the hose connections.
>
> "The tank was made of cold drawn steel, and the bottom was crimped and soldered and brazed in place. The explosion blew the butt end out, which went like a cannon ball, smashing and cutting off limbs of trees, and hitting the ground about 100 yards away.
>
> "The lead acid bottle following the end, hit a negro, cutting off his right arm and breaking his neck, causing instant death; the recoil knocked the wheels and the tank back about 25 feet, running over one man's leg and fracturing it in two places, and injuring three other people.

- -

"The engine was bought by the town about eight months ago, has been used at a number of fires, and has been recharged seven or eight times. The chief of the Fire Department stated that on the last charge, the one that caused the explosion, he had personally charged the engine, and had thoroughly washed it out and charged it accurately.

"The events happening between the sounding of the fire alarm and the explosion of the fire engine are, as follows: Four men pulled the engine from the engine house, the route to the scene of the fire (about 250 yards distant) included a steep incline (about 25 per cent grade) over a very rocky road for about half the distance, the engine accidentally turned over on the way down, but was immediately righted. On reaching the fire, it was noticed that the engine was generating pressure as the valve on the hose outlet was not tightly closed, and was leaking, the hose not being attached. Some one closed this valve tight, thus closing all outlets, and while the hose was being screwed on to the hose outlet the explosion occurred, with aforesaid results.

"About five minutes elapsed between overturning of the engine and the explosion. The recoil of the engine, after the explosion, broke several spokes in the wheels. No one had noticed the gauge reading during the action."

Another report of an explosion is quoted verbatim as follows.-

"The - - - extinguisher which exploded last__________, killing two men, was a device which had been installed at the factory for some little time, but was apparently in good condition and well cared for. An inspection of the tank after the explosion revealed that the top, which was blown off, seemed to be soldered to the body of the extinguisher only at intervals instead of a continuous bond of solder.

"The cyliner and head of the tank mentioned were both of steel, the cylindrical portion of the tank was seamless drawn with one integral head. The defective head was inserted into the end of this cylinder and the edge peined over the edge of the head before soldering. No rivets were used in the construction of this machine. The head parted completely from the cylinder; the rupture was violent, as indicated by the distance it was thrown from the machine through a 1-inch board 75 feet to the top of our foundry building."

PLAN OF INVESTIGATION.

The investigation was planned to yield data relative to the following features, - apparent life of chemical fire extinguishers, suitability of tank coatings, and the explosion hazard of extinguishers. It was divided into two parts; the first part consisting of a careful and minute examination of a number of extinguishers in the field, together with chemical analyses of the various tank coatings; and the second part, of a series of operation tests made under varying conditions with several extinguishers which had been in service for a number of years and found to be more or less corroded.

PART I. - EXAMINATION OF DEVICES IN SERVICE.

The sample extinguishers which were employed in this investigation were made by different manufacturers who, very probably, represent the largest companies producing devices of this type in the United States. All of

the extinguishers examined were of the acid and soda type; that is, the pressure within the tanks is generated by the action of sulphuric acid on sodium bicarbonate. The majority of the extinguishers examined were of the 33-gallon size, this being the size of the larger chemical extinguishers most commonly used; and the other sizes were 45-gallon and a few stationary extinguishers of 150 and 250 gallons capacity.

The 33-gallon extinguishers were of the inverting class, in which the acid is contained in a receptacle having a loose stopple and is fed to the soda solution by inverting the tank. The devices having a capacity of 45 gallons were of the break bottle class; that is, the extinguisher is put in operation by means of the operating mechanism provided, thus allowing it to act on the soda solution and generate the necessary pressure.

For identification purposes, all of the 45-gallon extinguishers were designated 1A, 2A, and so on; and the 33-gallon devices were designated as 1B, 2B, or either 1C, 2C,

etc., according to their manufacture.

RESULTS OF EXAMINATION.

Fifty 45-gallon extinguishers were examined, having been in service from two to eighteen years, averaging about ten years, and, in many cases, were the only fire apparatus available in the town. The devices were generally considered as having rendered very satisfactory service and practically no repairs, other than renewal of hose, had been necessary. The extinguishers were commonly stored in village halls or in sheds and, in some instances, were given practically no attention other than recharging them after they had been used. Examination of the tanks showed that the paint on the exterior was, in most cases, in good condition and that the interiors of the tanks were bright and showed no material evidences of corrosion or deterioration; the wheels were in good condition; and the operating mechanisms were easily operated.

One 150-gallon, and two 250-gallon

stationary chemical extinguishers were examined. The 150-gallon device was located in a warehouse of an oil company and was said to have been in service for seventeen years. One of the 250-gallon extinguishers was located in the basement and the other in the engine room of a varnish manufacturing plant, and both were said to have been in service for about fifteen or sixteen years.

The interior of the 150-gallon tank, below the solution level, was of a yellowish brown or slightly grayish color, and examination showed considerable rust above the solution level, especially around the hand-hole opening and at one end of the tank. The rust spots varied in color from very light brown to a very dark brown, being almost black at certain points.

Both of the 250-gallon tanks appeared to be in very good condition, considering the length of time for which they had been in service. No deterioration of material importance was visible in either tank. Examination of

the interior of these tanks showed the surface below the solution level to be of a very dark or indigo blue color, and of a light greenish color above the solution level.

Twenty-five extinguishers of the 33-gallon size, designated as the C devices, were inspected. These extinguishers were located in the vicinity of Chicago; four being used in department stores, three in railway stations, one in a machine shop, one in a paper supply plant, two in a brewery, two in a varnish works, five in a college, one at a glue works, and six in a packing plant. In examining each machine, especial attention was given to the condition of the tank interior, both above and below the solution level; to the condition of the acid receptacle and cage; whether the nozzle was in good working condition; and date when the device was last charged.

Every extinguisher of the 25 examined showed evidence of corrosion of the interior of the steel tank above or at the solution level, on both the cylinder and the dome, and nearly every one had a dark blue-colored deposit on

the cylinder head and bottom. The acid receptacles in a number of the machines were badly corroded and, in some places, both the copper sheath and the lead had been eaten or corroded through. Four of the tanks were badly corroded and they were believed to be in such condition that they would endanger the operator and perhaps others who might be in the vicinity, if they were to be operated. Ten extinguishers were found to be in what was considered a bad condition; some of these, and perhaps all, bordering on, if not actually being in, the dangerous class. Seven devices were in what may perhaps properly be termed fair condition; and the remaining extinguishers were considered as being in relatively good condition.

Three of the four extinguishers which were classed as dangerous were found in a packing plant and the fourth, in a railway station. The three machines located in a packing plant were found to have corroded so badly either right at or above the solution level that it

was necessary for the owner to patch the tanks to prevent leakage of the contents. Two of the extinguishers had bands of steel about 1/16 inch thick and about 2 to 2-1/2 inches wide extending almost entirely around them, soldered on the outside of the tanks at the solution level, to cover holes which were eaten through the tanks. In the case of one tank, the examiner counted eight fairly large holes, spaced approximately equidistantly around the tank, through which the inner surface of the steel repair band was, in some cases, visible. The tank of the third extinguisher was found to have two holes through it at the solution level, both of which had, according to the caretaker's statement, been plugged with solder to prevent leakage of the tank's contents.

The extinguisher located in the railway station was found to be covered with a dark indigo-blue, beady deposit, below the solution level. The interior of the tank above the solution level was covered with many large, rusty, and tuberculated patches, which extended around the cylinder and well up into the dome. The

tubercles in many places were built up as much as 1/8 inch in thickness.

These four extinguishers, classed as being dangerous, were obtained from the owners and taken to the Laboratories for the purpose of conducting the operation tests, as described in Part II of this thesis.

In addition to the above examination of the extinguishers, designated as C devices, the following information was obtained from the Manufacturer regarding other extinguishers of the same make.

> "Three 33-gallon extinguishers, sold on May 20, 1907, were found at a packing plant in Buffalo, one of which had been discarded in January, 1916, due to failure at the solution level. This extinguisher was taken to the Pump House for recharging and on the way it was noticed that the solution was running out of the side of the tank. The man in charge stated that he took a pencil and pushed it right through the tank at the solution level, and after emptying the extinguisher he found an encrustation about two inches wide and one inch thick around the entire circumference at the solution level, and that upon removing the same he found one place about six inches wide where the steel was entirely gone and a pencil could be pushed through almost any place around the circumference. The color of the incrustation was given as varying from light grayish brown to a very dark brown.

"The second extinguisher, located in the lard room, had a number of light rust spots below the solution level and above the center of the tank. There were patches in the head of the extinguisher above the solution level which were heavily corroded. These spots were about one inch wide and extended between the collar backing and the solution level. In all, there were about six or eight of these patches. The general appearance of the machine, however, was good.

"The third extinguisher, located in the sausage room, was dark gray to black above the solution level, and light gray below. Very little corrosion was evident except at the junction of the collar backing, where the rust was fairly heavy.

"Three 33-gallon extinguishers were sold to this same packing company on October 12, 1907. All three of these machines showed very little corrosion except at the junction of the collar backing. There were some scattered spots at the solution level on one machine. The other two were very free from corrosion. No corrosion was to be seen below the solution level. The general appearance of these tanks was grayish, being almost a black above the solution level, and light gray below the solution level.

"Three more 33-gallon machines were sold to this company on September 17, 1909. These extinguishers showed heavy corrosion above the solution level, and on one machine this corrosion extended to a distance of twelve inches below the solution level. The appearance of these machines was greenish to blue. Rust patches were to be found at the solution level and on one machine the corrosion extended almost entirely around the circumference at the solution level.

"A 500-gallon tank, located at a varnish plant in Chicago, Illinois, was found to be only slightly corroded above the solution level with a few patches of heavy rust, about the size of a half-dollar to

the size of a person's hand, on the top of the tank. Heavy corrosion was noticed around the collar backing.

"Another 500-gallon stationary chemical extinguisher located in an office building in Chicago, Illinois, showed very little corrosion at the solution level. The top of the tank was badly corroded. Rust, almost black in spots and blistering in appearance, was noticed directly above the acid receptacles.

"A 250-gallon stationary extinguisher located in a newspaper plant in Chicago, Illinois, was found to be heavily corroded above the solution level, and a large amount of flaky scale was found at the solution level and just above it. The scale formation was gray to grayish brown in color and had the appearance of blisters. The corrosion was very heavy over about one-half of the tank and these spots were dark brown to black.

"Another 250-gallon stationary extinguisher, located in a theater building in Chicago, Illinois, was found to be very heavily corroded above the solution level over the entire surface of the tank. The scale formation varied from a light grayish brown to a heavy dark brown above the acid receptacles.

"All of these stationary tanks have been in service from twelve to seventeen years and, for the period of service, could be said to be in very good condition."

Twenty-five 33-gallon machines, designated as B devices, were examined. All of these machines were located in New York City; eight of these were in a wholesale dry goods house, one in a clothing store, eleven in one

department store and one in another, three in a button manufacturing concern, and one in an exhibition hall. The manufacturer advised that all of these extinguishers had been sold sometime during the years 190[illegible] [illegible] 1906.

Of all the twenty-five extinguishers examined, the one located in the clothing store was found to be in the best condition. The interior of the tank below the solution level showed some indication of a pebbly, bluish deposit, and above the solution level there was a little evidence of rusting, but not sufficient to be considered bad. The extinguisher showed that it had apparently been given good care and attention.

The extinguisher located in the exhibition hall showed evidence of corrosion having eaten through the shell, the resulting holes having been partly filled with solder. The corrosion was still continuing and new pin holes were evidenced. The extinguisher was not kept in its normally upright position, but was pulled over so that the tank stood at an angle of approximately 45 degrees.

The eleven extinguishers examined in one department store were of a lot of about twenty-five extinguishers which were purchased by this company about 1902. These eleven extinguishers were taken out of service at various times during the years 1912 to 1915, the last one being removed from service in 1915.

Three of these eleven extinguishers were selected for the purpose of conducting tests upon them, as described in Part II of this thesis.

One of the three extinguishers, which were selected from the abandoned extinguishers, was found to be in fairly good condition and examination of the device showed no reason for its being abandoned. The interior of the tank at the upper portion showed a dark rusty band about three inches wide around the entire circumference, and portions of the tank below the solution level appeared as though the coating had drawn away from the tank.

All of the other abandoned extinguish-

ers were found to be in more or less poor condition, being quite rusty on the interior and showing signs of tuberculation along the solution level. Many of the tanks were found to be eaten through at the solution level, the holes in some cases being as large as 3/4 inch by 1/2 inch.

TESTS OF TANK COATINGS.

Six circular discs, exactly one inch in diameter, were cut from a shell of one of the 45-gallon extinguishers, designated at the A devices. Chemical analyses were made, using three of the discs, to determine the nature of the coating on the outside of the tank; and the remaining three discs were used to determine the nature of the coating on the inside of the tank. The results of these analyses showed that the tank was coated with pure zinc; the amount of zinc per square foot of coating on the outside of the tank was found to average 2.47 ounces, and on the inside of the tank the amount of zinc per square foot of coating averaged 3.39 ounces. The Manufacturer of these

extinguishers advised that all of these devices are lined in the same way and with the same materials.

The samples of the coating, taken from the outside of the 150-gallon stationary chemical extinguisher, when analyzed, showed the presence of zinc and steel. It was, therefore, concluded that the tank had been zinc coated. Sample tubercles or incrustations, taken from the inside of this tank above the solution level, when analyzed showed that lead and zinc, but no tin, were present. Slight traces of copper were also found. Samples taken from the inside surface of the tank below the solution level, were analyzed and zinc was found to be present, but no lead or tin.

Samples of the coating of the exterior of the 250-gallon stationary tank, which was found to be in the poorest condition of the two 250-gallon extinguishers examined, on analysis showed considerable zinc for the size of the samples employed. Samples taken from the in-

terior of the tank below the solution level showed the presence of considerable copper and zinc, for the size of the sample, but no lead or tin.

Samples of the coating [illegible] the extinguishers, located in the packing plant at Buffalo, N. Y., which was discarded, due to failure at the solution level, were removed from (1) the outside surface of the cylinder, (2) outside surface of the bottom, (3) inside surface of the dome, and (4) inside surface of the cylinder. Lead and tin were found to be present but no zinc was detected, indicating that the tank had been coated with a lead and tin alloy.

The following list of samples were taken from the 33-gallon extinguishers, designated as C devices, which were located in the packing company's plant at Buffalo, N. Y. Samples 1 to 5, inclusive, were taken from the extinguishers sold to this company on May 20, 1907. Samples 6 to 12, inclusive, were taken from extinguishers sold on October

12, 1907, and sample 13 was taken from an extinguisher sold on September 17, 1909.

Sample No. 1. - Sample of exterior coating from the extinguisher which had failed due to corrosion at the solution level showed that lead and iron were present but no zinc, indicating that the tank was coated with a lead and tin alloy.

Sample Nos. 2 and 3. - Samples taken from above and from below the solution level, respectively, of an extinguisher located in the lard room of this packing company, showed the presence of nothing except tin, lead, and iron. These results quite clearly indicate that this extinguisher tank was coated with a lead and tin alloy.

Sample No. 4. - Samples taken from above and from below the solution level, respectively, of an extinguisher located in the sausage room of this plant, showed the presence of lead, tin, and iron, but no zinc, clearly indicating that the tank was coated with a lead and tin alloy.

Sample Nos. 6, 7 and 8. - Samples taken from below the solution level, from above the solution level, and from the outside of the tank located in the smoke house of this plant. Samples Nos. 6 and 7 showed the presence of tin, lead, zinc, and iron, while Sample No. 8, taken from the outside of the tank, showed only lead and iron.

Sample No. 6, taken from below the solution level, and from the interior of the tank, showed a large amount of zinc, but only a trace of tin and a small amount of lead; while Sample No. 7, taken from the interior of the tank above the solution level, showed a large amount of tin and lead, but only a small amount of zinc. The lead and tin found in the samples taken from both above and below the solution level is accounted for by the fact that the collar of the tank and the junction of the head and the shell are backed up with solder. The solder is poured in and sweated around the joints and extends down below the level of the solution in the tank.

The finding of lead in the sample taken from the outside of the tank is accounted for by the fact that the sample was taken from the head of the tank, near the collar, and that this collar and its rivets are sweated in with solder, some of the solder always remaining on the outside. The failure to detect the presence of zinc in this sample is probably accounted for by the fact that the head was most likely placed in a shallow bath of acid before setting it in place, thus removing the zinc.

Sample Nos. 9 and 10.- Samples taken from below and above the solution level, respectively, of an extinguisher located in the new rest room of this plant. Sample No. 9 showed a large amount of zinc and a medium amount of lead, with a large amount of tin. Sample No. 10 showed a small amount of zinc and a trace of tin and a large amount of lead.

Sample Nos. 11 and 12. - Samples taken from below and from above the solution level,

respectively, of an extinguisher located in the canning room of this plant. Sample No. 11 showed a large amount of zinc with a small amount of lead and tin, while Sample No. 12 showed a medium amount of zinc with a large amount of lead and tin, which might reasonably be expected, since the first-named sample was taken from below the solution level on the interior of the tank, and the last-named was taken from above the solution level on the interior of the tank.

Taking into consideration all of the evidence developed by means of analysis of sample coatings and deposits in connection with these samples, it would seem that the extinguishers from which Samples Nos. 6 to 12, inclusive, were taken were very likely galvanized tanks.

Sample No. 13. - Sample taken from above the solution level of an extinguisher located in the box room of the packing plant showed a large amount of lead and a medium amount of tin, with a large amount of iron and no zinc, indicating

that the extinguisher from which this sample was taken had a tank coated with a lead and tin alloy.

Five samples of the coating of one of the three 35-gallon extinguishers, designated as C devices, which were found in the packing plant at Chicago, Illinois, and classed as dangerous, were analyzed. One sample was taken from the bottom of the extinguisher; one from the outside of the cylinder, the paint being first very carefully removed with a varnish remover; one from the inside of the tank above the solution level; and two from the inside of the tank below the solution level. All of the samples analyzed showed the presence of lead, tin, and iron, but none showed the presence of zinc, indicating that the extinguisher from which these samples were taken was coated with a lead and tin alloy.

The Manufacturer advised that all of the extinguishers which were designated as B devices were coated with a lead and tin alloy.

PART II. - OPERATION TESTS.

DESCRIPTION OF SAMPLES AND TEST APPARATUS.

The extinguishers used in these tests were the three machines, designated as B devices, which were chosen from the eleven abandoned devices which had been located in the department store at New York City; and four extinguishers, designated as C devices, three being taken from a packing plant and one from a railway station in Chicago, Illinois; all four being classed as dangerous. The B devices were numbered 1B, 2B, and 3B; and the C devices, 1C, 2C, 3C, and 4C, for identification purposes.

Machine No. 1B. - This extinguisher, when received for test, contained nine holes ranging in size from a 3/32-inch round hole to one 3/4 by 7/16 inch, rectangular in shape. These holes extended around the shell on a line about 5-1/2 inches below the center line of the hose-connection fitting. The interior of the tank was badly encrusted at the same distance below the hose-connection

as the holes were. The general appearance of the device is shown by Figure 1.

Machine No. 2B. - This extinguisher contained two holes, one being [illegible]/16 by 13/32 inch in size, and the other, 3/8 by 5/32 inch. The distance from the hose connection down to these holes was 8-3/4 inches, and the interior of the tank was found to be encrusted on a line even with these holes. The general appearance of the device is shown by Figure 2.

Machine No. 3B.- This extinguisher had no holes through the shell and no indication of any bad spots, it being the device, out of the lot of eleven abandoned extinguishers, for which no reasons could be found from examination for its being abandoned. A band of incrustations was observed on the inside of the shell at about the filling level.

Machine No. 1C. - This extinguisher had twelve holes, extending around the shell at the solution level and ranging in size from pencil point holes to those 1/4 by 1 inch. Two bands were soldered on the outside of

Fig. 1.

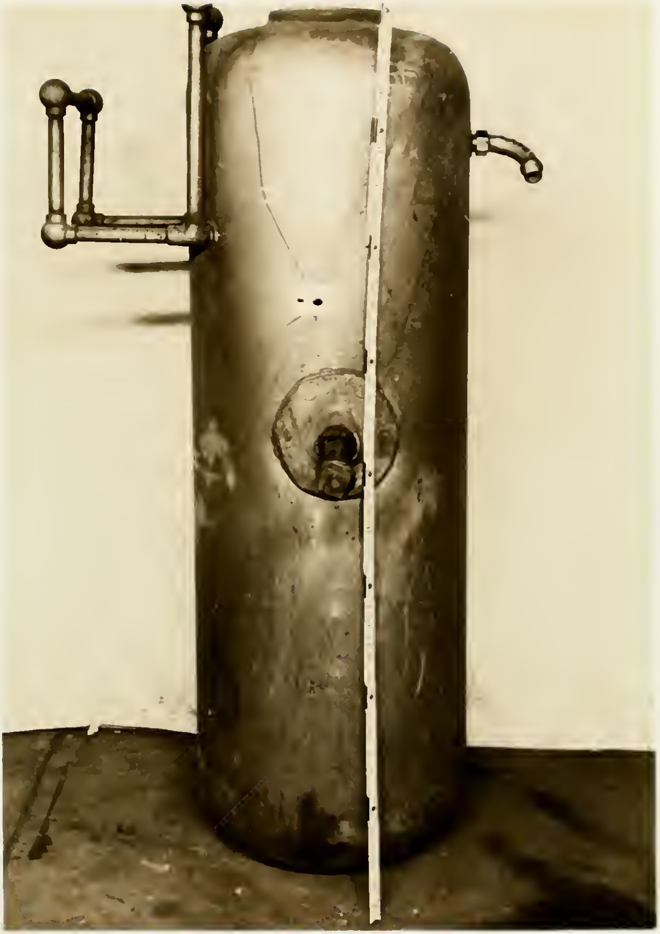

Fig. 2.

the shell; one band extending between the hose supporting brackets; and the other, the rest of the way around the tank. The general appearance of the device is shown by Figure 3.

Machine No. 2C.- This extinguisher had three holes in the shell, observing from the inside, ranging in size from a pin hole to 3/16 by 1/2 inch. The tank was heavily incrusted on the inside at the filling level. Two bands were soldered to the outside of the tank at the solution level, each band extending half way around the tank. The general appearance of the device is shown by Figure 4.

Machine No. 3C.- This extinguisher had two lead plugs near the hose supporting brackets and on a line just above these brackets. A heavy incrustation was found on the interior of the tank at the filling level. The general appearance of the device is shown by Figure 5.

Machine No. 4C.- This extinguisher was quite badly corroded on the interior of the tank at the filling level, but no holes were discernible.

Fig. 3.

Fig. 4.

Fig. 5.

In order that the extinguishers might be operated with safety, they were placed in a pit 5 feet square and 5 feet deep, the top of which was covered with a heavy two-ply door, weighted down with sand bags. The tanks were placed in operation; that is, inverted, by means of a cord running over a system of pulleys and passing out through an opening in the top of the pit.

The pressures generated in the tanks were read on a pressure gauge, located at some distance from the pit, and connected to the tanks by means of patrol hose; the connection at the tank being made at a tapped opening provided in the cap of each device. The patrol hose was brought out through an opening in the pit.

The extinguishers were charged in the pit, the water being pumped up from the basement of the hydraulic laboratory by a small duplex pump.

Figures 6 and 7 show an extinguisher in the pit before and after inverting. The

Fig. 6.

Fig. 7.

cable for inverting passes over the pulley shown in the extreme lower portion of Figure 7, around a small pulley at the bottom of the pit, and then up to the cap. The sash cord was used to prevent the tank from turning too far, and also to pull it upright after the test. The hose leading to the gauge (gauge not shown in picture) can be plainly seen leading out, in the lower left-hand corner of the picture. The discharge hose was brought out through the square opening in the top plank, as shown in the upper portion of the picture. Some idea of the size of the pit and the extinguisher can be gotten from the two rulers laid along the edge of the pit.

TEST METHODS.

The extinguishers were filled with water, at a known temperature, up to the normal filling level, namely, 33 gallons. Soda was then put in and the solution stirred until all of the soda was completely dissolved. Acid was put into the acid receptacle which was then placed into the extinguisher, the

top or cap screwed on and the device was ready to operate. The soda and acid were both weighed before being put into the tank; in some cases the normal charge of 20 pounds of soda and 7 pounds of acid was used, while in other trials varying amounts of soda and acid were employed. The temperature of the solution after the soda had been dissolved was very carefully taken by means of a Fahrenheit thermometer.

In some trials or tests the discharge outlet was kept open, that is, open nozzle tests; and in other tests, it was kept closed, or closed nozzle tests. The pressures developed in the tanks were recorded every ten seconds at the pressure gauge, which was very carefully calibrated at frequent intervals throughout the tests. Samples of the liquid residue in the tanks after operation were tested with litmus paper for acid or alkaline reactions.

Observations were made in every case for any leaks that developed or any injuries to the tanks or fittings. Leaks were repaired, when the condition of the shell was such that

it allowed pressure to escape too rapidly, but the nature of the repair work was such that no strength was added to the shell.

In addition to these operation tests, Machine 3B and Machine 4C were subjected to hydrostatic pressure tests before the operation tests were conducted. In the hydrostatic pressure tests, each device was completely filled with water, the cap and outlet fitting tightly closed, and pressure applied by means of a triplex power pump at the rate of 100 pounds per minute.

RESULTS OF TESTS.

Machine No. 3B, when subjected to a pressure of 300 pounds per square inch in the hydrostatic pressure test, showed no leakage other than a slight amount at the cap threads.

Machine No. 4C, when subjected to a pressure of 200 pounds per square inch in the hydrostatic pressure test, developed a pinhole leak about midway between the hose supporting brackets and eight inches below the handles. The pressure was then increased to

400 pounds per square inch and held for three minutes and no additional points of leakage were observed.

The following results were obtained in the operation tests:

MACHINE NO. 1B.

Test No. 1. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure 55 pounds, obtained in 10 seconds.

The pressure decreased rapidly as the liquid was blown through the nine holes in the shell. The holes were then filled with lead, for the next test.

Test No. 2.- Closed Nozzle Test - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure 143 pounds, obtained in 40 seconds.

As a result of this test, a new hole opened up in the tank and the pressure escaped very rapidly, entirely dissipating itself in 260 seconds. The holes were filled and, when the holes were close together, the plugs were

joined, making one large plug instead of two smaller ones, prior to the next test.

Test No. 3.- Closed Nozzle Test - 20 pounds of soda and 7 pounds of acid. Solution temperature 70 degrees, Fahrenheit. Maximum pressure, 186 pounds, obtained in 70 seconds.

The plugs held the pressure fairly well, but quite a leak was noticed around the cap. The pressure was reduced to 110 pounds in one hour and 47 minutes, after which the nozzle was opened and the solution allowed to escape. Three 1/16-inch gaskets were placed in the cap after this test to prevent any further leakage in the following tests.

Test No. 4.- Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 165 pounds, obtained in 40 seconds.

In 16-1/2 minutes the pressure was reduced to 108 pounds, after which the tank was righted and then tipped again. The pressure then went up to 118 pounds, and in 29 minutes was reduced to 84 pounds. The nozzle was then

opened and the solution allowed to escape. A small hole, about the size of a pencil point, was discovered when the tank was examined after the test, and this hole was plugged with lead before the next test was conducted.

Test No. 5. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 221.5 pounds, obtained in 80 seconds.

In 40 minutes the pressure had dropped to206 pounds, the nozzle being then opened and the solution allowed to escape.

Test No. 6. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 90 degrees, Fahrenheit. Maximum pressure, 300.5 pounds, obtained in 60 seconds.

In 97 minutes the pressure had dropped to 208 pounds, due to a slight seeping out around the plugs and to slight leakage at the nozzle cock.

Test No. 7. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 111 degrees, Fahrenheit. Maximum

pressure, 203 pounds, obtained in 70 seconds.

The pressure dropped to 108.5 pounds in 54 minutes. Examination of the tank showed that a new small hole had opened up, and several spots looked as though they were ready to break through.

Test No. 8.- Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 120 degrees, Fahrenheit. Maximum pressure, 300 pounds, obtained in 30 seconds.

The pressure was completely dissipated in 8 minutes and 40 seconds. A copper patch, which had been soldered on, blew off in this test.

Test No. 9. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 115 degrees, Fahrenheit. Maximum pressure. 327 pounds, obtained in 70 seconds.

The discharge hose blew off at the 145th second, the pressure being 326 pounds. No new leaks could be discovered.

A test was next attempted with a solu-

tion temperature of 122 degrees, Fahrenheit, but the hose was blown off at the 20th second, the pressure being 217 pounds.

Test No. 11. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 123 degrees, Fahrenheit. Maximum pressure, 372 pounds, obtained in 60 seconds.

The pressure dropped to 163 pounds in 40 minutes, after which the nozzle was opened and the solution allowed to escape. Leakage around two of the plugs in the shell was noticed.

Test No. 12. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 122 degrees, Fahrenheit. Maximum pressure, 415 pounds, obtained in 60 seconds.

The pressure dropped to 273 pounds in 40 minutes and was then released. Slight leakage around the plugs in the shell was noticed.

MACHINE NO. 2B.

The two holes in the shell were filled with lead, but in doing this the workman punched

three more holes, and these were also filled with lead.

Test No. 1. - Closed Nozzle Tests - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 140 pounds, obtained in 40 seconds.

A new hole opened up in the shell and allowed all of the pressure to escape in 190 seconds. This hole was plugged with lead before conducting the next test.

Test No. 2. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 230 pounds, obtained in 60 seconds.

A loud, hissing noise was heard when the pressure reached 210 pounds and examination of the device showed that this was due to another hole which had opened up. Indications of possible future blow-outs were also noted when the shell was examined after the test. Prior to the next test, the new hole was plugged with lead.

Test No. 3.- Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 224 pounds, obtained in 70 seconds.

In 70 minutes the pressure had dropped to 214 pounds, and after 17 hours and 10 minutes, the pressure had dropped to 22 pounds, due to leakage around the cap. No new holes developed, although several bad spots gave promise of future blow-outs.

Test No. 4. - Closed Nozzle Test.- 20 pounds of soda and 7 pounds of acid. Solution temperature, 90 degrees, Fahrenheit. Maximum pressure, 297.5 pounds, obtained in 60 seconds.

The pressure in the tank fell to 155 pounds in 40 minutes, due to leakage around the plugs. No new holes developed as a result of this test.

Test No. 5. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 119 degrees, Fahrenheit. Maximum pressure, 275 pounds, obtained in 140 seconds.

The pressure dropped to 270 pounds in

33 minutes, after which it was released by opening the nozzle valve.

Test No. 6. - Closed Nozzle Test.- 20 pounds of soda and 7 pounds of acid. Solution temperature, 122 degrees, Fahrenheit. Maximum pressure, 285 pounds, obtained in 120 seconds.

The pressure dropped to 273 pounds in 11 minutes, when one of the plugs in the shell began to leak badly, the pressure falling from 273 to 15 pounds in 47 minutes.

Test No. 7. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 126 degrees, Fahrenheit. Maximum pressure, 335 pounds, obtained in 40 seconds, when the tank burst.

The shell was completely wrecked, being split from top to bottom. The bottom was intact and fell down inside the shell; the acid receptacle also burst, due apparently to internal pressure in the receptacle.

Figures 8, 9, 10, 11, 12, and 13, show the extinguisher after the wrecking of the shell. In Figures 9 and 10 the bottom can be seen as it

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

fell in the inside of the shell. Figure 13 shows the head and body of the acid receptacle, the bottom of which had bulged out so far as to burst the outer shell.

MACHINE 3B.

Test. No. 1. - Open Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 69 degrees, Fahrenheit. Maximum pressure, 130 pounds, obtained in 30 seconds.

A pressure gauge was attached close to the collar cap of this extinguisher and another at the end of 30 feet of patrol hose; both gauges being connected to the interior of the tank, to ascertain if differences in location of the gauge would cause variation in the pressure readings. It was found that the differences between the pressures read at the tank and those read at the end of the patrol hose were so small as to be negligible.

Test No. 2. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 182 pounds, obtained in 50 seconds.

The nozzle was opened at the end of the 70th second and the pressure released. Two pressure gauges, connected as described in Test No. 1, were employed and as in the latter test, the pressure readings checked very closely.

Tests Nos. 1 and 2 were run in the hydraulic laboratory, and the following tests were run in the pit.

<u>Test</u>. <u>No</u>. <u>3</u>.- Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 120 degrees, Fahrenheit. Maximum pressure, 409 pounds, obtained in 250 seconds.

<u>Test</u> <u>No</u>. <u>4</u>. - Closed Nozzle Test. - 30 pounds of soda and 9 pounds and 13 ounces of acid. Solution temperature, 120 degrees, Fahrenheit. Maximum pressure, 410 pounds, obtained in 25 seconds, when the patrol hose blew off at the pressure gauge connection.

<u>Test</u> <u>No</u>. <u>5</u>. - Closed Nozzle Test. - 30 pounds of soda and 9 pounds, 15 ounces of acid. Solution temperature, 120 degrees, Fahrenheit. Maximum pressure, 475 pounds.

obtained in 30 seconds, when the patrol hose again blew off at the gauge connection. It was discovered upon examining the tank after the test, that the bottom of the extinguisher was tearing loose from the shell around the seam.

Test No. 6. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 122 degrees, Fahrenheit. Maximum pressure, 377 pounds, obtained in 120 seconds.

The pressure decreased to 255 pounds and at the 270th second the patrol hose blew off at the gauge connection. The shell was found to be leaking slightly in two places around the seam at the bottom.

Test No. 7. - Closed Nozzle Test.- 20 pounds of soda and 7 pounds of acid. Solution temperature, 116 degrees, Fahrenheit. Maximum pressure, 315 pounds, obtained in 40 seconds.

The pressure dropped to [illegible]2 pounds in 37 minutes, after which it was released through the nozzle. The bottom of the tank was found to be leaking in three places. The stopple in the acid receptacle was removed in this test.

Test No. 8.- Closed Nozzle Test. - 25 pounds of soda and 8 pounds of acid. Solution temperature. 120 degrees, Fahrenheit. Maximum pressure. 295 pounds, obtained in 10 seconds, when the petrol hose blew off at the gauge connection. The bottom was found to be leaking in three places. The stopple was removed from the acid receptacle in these tests.

Test No. 9.- Closed Nozzle Test. - 25 pounds of soda and 8 pounds of acid. Solution temperature, 120 degrees, Fahrenheit. Maximum pressure, 360 pounds, obtained in 20 seconds, when the hose blew off at the gauge connection.

Examination of the tank after the test showed a crack about 10 inches long where the bottom was joined to the shell. In this test the stopple was removed from the acid receptacle.

Test No. 10. - Closed Nozzle Test. - 25 pounds of soda and 8 pounds of acid. Solution temperature, 120 degrees, Fahrenheit. Maximum pressure, 360 pounds, obtained in 30 seconds, when the bottom blew out of the shell. The stopple was not in the acid receptacle during this test.

The recoil tore one axle out of the flange casting and bent the other axle. Figure 14 shows the extinguisher in the pit, just as it appeared after the test. Figure 15 shows the scratches on the edge of the bottom head, and Figure 16, the scratches on the inside of the shell which were made by the bottom as it was forced out of the shell. Figure 17 shows the extinguisher as it appeared set up in the yard. The bottom and acid receptacle are shown between the wheels.

MACHINE NO. 1C.

<u>Test</u> <u>No</u>. <u>1</u>. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 193 pounds, obtained in 30 seconds.

A hissing noise was heard and all of the pressure escaped in 330 seconds, due to a leak which developed.

<u>Test</u> <u>No</u>. <u>2</u>. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 90 degrees, Fahrenheit. Maximum pressure, 135.7 pounds, obtained in 30 seconds.

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 17.

This test was run without repairing the leak which developed in Test No. 1. The pressure had entirely escaped in 120 seconds. The band, which had been soldered to the tank, was forced out about 1/4 inch from the shell and a 2-inch crack had opened in the solder at a point where one of the holes in the shell was located. This crack was soldered up before running the next test.

Test No. 3.- Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid, Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 185 pounds, obtained in 20 seconds.

A loud hissing noise was heard which increased in intensity after the pressure had dropped to 89 pounds. All the pressure had escaped in 130 seconds. Examination of the tank showed that a new crack, about 1-5/8 inches long had opened up. The first leak developed in the tank in Test No. 2 was plugged with lead on the inside of the shell, and the new leak, which developed in this test, was soldered up before running Test No. 4.

Test No. 4. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 200 pounds, obtained in 30 seconds, when the band blew out around the solder at the newly soldered joint. The cracks were again soldered up.

Test No. 5. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 200 pounds, obtained in 25 seconds, when the crack opened up again.

A new crack developed at the bottom of the band just opposite the soldered place at the top of the band. All of the pressure escaped in 130 seconds. The bands were then taken off and the holes plugged, to ascertain whether this method of repairing the tank was more effective than the former. Figures 18, 19, and 20 show the holes in the shell after the bands were removed. Twenty-three holes were found in the shell after the bands were removed.

Fig. 18.

Fig. 19.

Fig. 20.

Test No. 6. - Closed Nozzle Test. - 20 pound of soda and 7 pounds of acid. Solution temperature, 70 degrees. Fahrenheit. Maximum pressure, 200 pounds, obtained in 70 seconds.

Two plugs were found to be leaking quite badly and the pressure dropped to 147 pounds in 31 minutes and 50 seconds, when the pressure was released through the nozzle. The plugs were repaired before running Test No. 7.

Test No. 7. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 206 pounds, obtained in 60 seconds.

The plugs were again found to be leaking quite badly and the pressure ran down to 141 pounds in 32 minutes, after which it was released by opening the nozzle. The plugs were again repaired and one new plug added where there was evidence of a new hole.

__Test__ __No__. __8__. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 7[illegible] degrees, Fahrenheit. Maximum pressure, 19[illegible], obtained in 60 seconds.

Two plugs were again found to be leaking quite badly and the pressure was reduced to 69 pounds in 30 minutes, after which the nozzle was opened and the pressure released. The plugs were again repaired, prior to running Test No. 9.

__Test__ __No__. __9__. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 7[illegible] degrees, Fahrenheit. Maximum pressure, 218.5 pounds, obtained in 60 seconds.

The pressure dropped to 173 pounds in 60 minutes, after which it was released. The same two plugs that were leaking in Test No. 8 again failed to hold the pressure in this test.

__Test__ __No__. __10__. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 91 degrees, Fahrenheit. Maximum pressure, 240.5 pounds, obtained in 60 seconds.

In 50 minutes after the start of the tests, the pressure had dropped to 77 pounds and was then released through the nozzle. The plugs were found to be leaking badly. Three new spots were repaired and a patch was put on to replace the plug which, it seemed, could not be made to hold pressure.

Test No. 11.- Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 116 degrees, Fahrenheit. Maximum pressure, 225 pounds, obtained in 50 seconds.

The pressure was entirely released in 320 seconds after the start of the test. The patch on the shell was blown off and a new hole opened up. A crack, about 5 inches long, was discovered in the shell on a line with the holes. A plug was put into the shell at the place where the patch was.

Test No. 12. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 118 degress, Fahrenheit. Maximum pressure, 308 pounds, obtained in 80 seconds.

The pressure dropped to 140 pounds in 40 minutes, after which the nozzle was opened up. Three plugs in the crack on the shell were found to be leaking badly in this test.

Test No. 13. - Closed Nozzle Test. - 20 pounds soda and 7 pounds acid. Solution temperature, 120 degrees, Fahrenheit. Maximum pressure, 276 pounds, obtained in 40 seconds.

The plugs in the crack in the shell leaked so badly that the pressure was entirely released in 400 seconds after the start of the test.

Test No. 14. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 122 degrees, Fahrenheit. Maximum pressure, 302 pounds, obtained in 40 seconds.

The shell leaked so badly at the crack that the pressure was entirely released in 270 seconds. Two steel patches were welded to the shell over the crack.

Test No. 15. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution

temperature, 120 degrees, Fahrenheit. Maximum pressure, [illegible] pounds, obtained in 70 seconds.

The pressure fell to 22[illegible] pounds in 40 minutes, after which it was released through the nozzle. Several plugs were found to be leaking badly and the welded patches were found to be leaking somewhat.

Test No. 16.- Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 117 degrees, Fahrenheit. Maximum pressure, 296 pounds, obtained in 35 seconds, when the head blew off around the line of the holes in the shell.

In this test the stopple was taken out of the acid receptacle. The recoil blew the tank up against the wooden door covering the pit, leaving an imprint of the bottom on the door. Figures 21, 22, and 23 show the tank in the pit and after it was set up in the yard. The pictures show clearly the ragged edge at the break, indicating how the shell was weakened by corrosion, the metal being eaten al-

Fig. 21.

Fig. 22.

Fig. 23.

most entirely away practically all around the shell.

MACHINE NO. 23

<u>Test</u> <u>No</u>. <u>1</u>. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 144.5 pounds, obtained in 15 seconds.

The band was forced out about 1/8 inch from the shell, the solder cracking loose in three places. These three places were soldered up before running the next test.

<u>Test</u>. <u>No</u>. <u>2</u>. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 177 pounds, obtained in 25 seconds.

The band again blew out at the two newly soldered places, making the cracks longer, and releasing all of the pressure in 310 seconds. The leaks were soldered up and lead was run into the holes from the inside of the shell.

<u>Test</u>. <u>No</u>. <u>3</u>. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum

pressure, 196 pounds, obtained in 40 seconds.

A hissing noise was heard at the end of 20 seconds, when the pressure stood at 175 pounds. All of the pressure was released in 19 minutes and 10 seconds. One new crack and one old crack were opened up in this test, and the band was bulged out considerably.

MACHINE NO. 3C.

Test No. 1. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 181 pounds, obtained in 50 seconds.

A small pin hole developed in the shell and all of the pressure escaped in 610 seconds. The pin hole was plugged with lead before running the next test.

Test No. 2. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 70 degrees, Fahrenheit. Maximum pressure, 253 pounds, obtained in 90 seconds.

In 17 hours and 10 minutes after the start of the test, the pressure had dropped to 225 pounds, and it was then released by opening the nozzle. No new holes developed as a result of this test.

Test No. 3. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, [illegible] degrees, Fahrenheit. Maximum pressure, [illegible] pounds, obtained in 60 seconds.

In [illegible] hours and 19 minutes after the start of the test, the pressure had dropped to 258 pounds, the nozzle being then opened and the pressure released. No evidence of any leaks were found in the shell. A broken coupling on the patrol hose was found, but it did not appear that this had caused any leaks.

MACHINE NO. 4C.

Test No. 1. - Open Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 71 degrees, Fahrenheit. Maximum pressure, 207 pounds, obtained in 370 seconds.

The nozzle was opened up at the end of the 370th second and the pressure was entirely released at the end of the 500th second. A leak around the cap was observed, due to a broken gasket, and it was also found that the acid bottle had not emptied as it should have, so another test was run as a check.

Test No. 3. - Closed Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 72 degrees, Fahrenheit. Maximum pressure, 234.5 pounds obtained in 120 seconds.

The nozzle was opened up at the 210th second and all of the pressure had escaped in 340 seconds from the start of the test. Slight leakage was noted from the pin holes in the shell.

Test No. 4. - Open Nozzle Test. - 20 pounds of soda and 7 pounds of acid. Solution temperature, 69 degrees, Fahrenheit. Maximum pressure, 133 pounds, obtained in 30 seconds.

The pressure was entirely released in 120 seconds from the start of the test.

CONCLUSIONS.

As a result of this investigation of the service record of chemical extinguishers, it is believed that steel tanks coated with a lead and tin alloy are not suitable and do not satisfactorily serve their purpose, even though it was found that the life-time of some of the devices examined was ten to twelve years, or even longer.

A large proportion of the steel extinguisher tanks examined were found to be coated with lead and tin alloy, which is quite commonly used to protect chemical extinguisher tanks against internal corrosion, due either to the chemical used, or formed, when the extinguishers are operated. These tanks were found, in many cases, to be so badly corroded after periods of service ranging from about 10 to 14 years, as to require removal of the extinguisher from service, or plugging of the holes with lead or solder and patching with copper or steel bands to prevent leakage of their solution contents.

The steel tank, coated with zinc by the hot-galvanizing process and employed for chemical extinguishers of a type differing in some respects from the inverting type but not to an extent which, it is believed, makes it improper to compare the two types from the standpoint of corrosion, showed very much less evidence of deterioration, and the indications are that their average life is probably at least double that of tanks coated with lead and tin.

The facts presented in the above paragraphs are substantiated by theory. The three leading theories which have been lately put forward as to the initial cause of corrosion are, the hydrogen peroxide theory, the carbon dioxide theory, and the electrolytic theory. Of these three theories, the electrolytic theory is the most generally accepted at the present time and is based, fundamentally, upon the solution pressure of metals.

When a metal is immersed in a solution of its own salt, there are two forces acting in opposition. Corresponding to the magni-

tude of the solution pressure, ions of the metal are tending to enter the solution, and in the same manner, according to the magnitude of the osmotic pressure, ions of the metal in the solution tend to pass back and deposit upon the metal. The first tends to impart positive electricity to the solution, and the second tends to impart a positive charge to the metal.

If the two forces are equal, no difference in potential exists between the metal and the solution, but if one force is greater than the other, an electric potential is immediately developed between the solution and the metal. A practical illustration of this phenomenon is the galvanic battery, in which there is a combination of two single potentials, or of two different metals immersed in solution and producing, if the proper metals are selected, a potential equal to the sum of the single potentials of each metal and its solution.

The difference in potential of a metal and its solution can be readily measured, and is known as the single potential measurement.

The electrolytic theory is applicable to the case of corrosion, in that all metals are, to a certain extent, impure. Even though this impurity is minute in form and amount, it is sufficient to cause innumerable cells, producing potential differences between the metal and the impurity, thereby causing solution of the metal or impurity, depending upon which is the anode or cathode, this being determined by the potential of each.

The case may be extended further, to metals with metallic coatings. Any coating which has a single potential positive to the metallic base, which it is supposed to preserve, may be considered as an inhibitor or retarder of corrosion to that base. The term "positive" refers to the commonly accepted term of the potential of the metal to its solution. For instance, zinc is said to have a single potential of + 0.493 volts; meaning the solution has a positive charge of electricity of 0.49 volts above that of the metal.

Any coating which has a negative potential to the metallic base may be considered as an accelerator of corrosion to that base.

The following table gives a brief list of the single potential series of a few of the metals:

Zinc	+	0.493 volts
Iron	+	0.063 volts
Tin	−	0.085 volts
Lead	−	0.129 volts

From the above table it may be seen that an iron shell or tank preserved by means of a zinc coating would not only have the protection due to the covering ability of the coating alone, but, also, of any galvanic action which may arise, in which the zinc would be the anode and the iron base, the cathode; resulting in the final disintegration and solution of the zinc coating, and, during the life of the coating, in the preservation of the iron base.

Actual service records show that iron may be preserved by zinc in such a manner, even though the coating is porous and the iron ex-

posed in many minute points. In other words, the coating may be scratched or marred, but so long as sufficient zinc remains within a definite distance of the exposed point, the iron will be preserved and no corrosion result.

Taking the case of an iron base coated with lead, or a lead and tin alloy, it will be seen from the above table that these metals are negative, in single potential, to the iron; and their protection, therefore, lies entirely in their covering power. A scratch or marred spot exposes the iron base and thereby sets up, under favorable circumstances, a galvanic action, in which the iron becomes the anode and the coating, the cathode (note that this is the reverse to the first case of the iron and zinc). Corrosion proceeds at a rapid rate and finally undermines the base under the coating, resulting in destruction of the base and disintegration of the coating. It will be seen that in this case, instead of the coating preserving the base, the base actually has a tendency to preserve the coating.

Therefore, in the case of lead, lead and tin alloy, or any other metallic coatings with a negative single potential to the base, unless the coating is extremely heavy and absolutely free from any pin-points, scratches, and the like, there will always be a tendency for the base to corrode at the exposed points, with the additional stimulative effect of the negative coating.

From the above, it can be seen that the results of the examinations made of the extinguishers, are substantiatednby theory, and that a zinc coating is preferable to a coating of lead and tin. The bicarbonate of soda solution has extremely little action upon the zinc coating, so that the zinc is not at all likely to dissolve or disintegrate, thus giving long life to the coating and the base or extinguisher shell.

The results of the operation tests made to investigate the explosion hazard, in which a number of old and more or less badly corroded

extinguishers were operated, with various chemical charges -- the charges and solution temperatures in a number of cases being very much in excess of the normal and in some cases, as a matter of fact, probably in excess of charges and temperatures which it seems reasonable to expect would often be encountered under actual service conditions -- indicate that if the extinguishers are so designed that proper strength is obtained in the joint between the cylinder and the bottom, or in the joints between the cylinder and the dome and the bottom, there is little likelihood of any explosion occurring, even though the tank has corroded through in places. It was found in the tests conducted that where there were holes in the tank, -that is, where the steel had corroded entirely through,- such holes acted as vents to relieve pressure and that if a sufficient number of holes of appreciable size developed, excessive or dangerous pressures would not be obtained. It should be borne in mind, however, that even though the results of these

experiments gave the indications above mentioned, they do not conclusively prove that corrosion may not in some instances be a contributory cause of explosion of these devices.